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STERILIZABLE LIQUID PROPULSION SYSTEM

Third Quarterly Progress Report

July 1967

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FOREWORD

This document is the third issue of the Quarterly Progress Report and is submitted in accordance with Article 1(a)(1)(v)(E) and 2(b)(5) of JPL Contract 951709.

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I. INTRODUCTION

This is the third quarterly progress report submitted in accordance with JPL Contract 951709. The report covers the period from 1 April 1967 thru 30 June 1967.

The program involves the exposure of an assembled and fueled bipropellant liquid propulsion system to the ethylene oxide (ETO) and heat sterilization environments specified by JPL specification VOL 50503 ETS. After exposure, the system will be fired for 300 sec.

The program plan includes a design and component selection phase during which the propulsion system design is evolved. A second phase will involve the procurement of components for both a component test series and for assembly into the complete system. The third phase of the program, which is being carried on in parallel with the design phase, is a materials investigation. During this phase, data are being collected and testing is taking place. Where data do not exist, testing is being conducted to provide the necessary information. The fourth phase of the program involves the assembly and test of the complete propulsion system. The system will be assembled and propellents loaded and then exposed to ETO and heat sterilization cycles. No attempt will be made to sterilize or to verify sterilization. The intent is to prove the feasibility of exposing a loaded bipropellant propulsion system to both the ETO and heat sterilization environments without system degradation. This will be proved by a 300-sec hot firing of the system immediately after exposure to the environments. As a final verification the system will be disassembled and the component parts tested and inspected for degradation.

During this report period the detail design of the module was completed and released for fabrication. Seventy-five percent of the components have been accepted. Test fixtures for the baseline testing have been designed, assembled, and checked out. All procedures for component baseline testing were completed and submitted for approval. Component baseline performance tests were 40% complete.

The facility modifications to the sterilization chamber have been completed and qualification tests were 90% complete.

The long-term storage tests of the small-scale propellant tanks have been initiated. The exposure to high temperature propellant has been completed and the specimens are in room temperature storage for a year.

During the next report period all components are to be delivered and subjected to the dry heat sterilization cycles. The final assembly of the propulsion system is scheduled to start early in September.

II. CONCLUSIONS

The following conclusions were made resulting from the work performed during this period:

1) Normal steel welding practices that allow formation of oxides are not acceptable for sterilization in hydrazine-based fuels;

2) Seam welding of faying surfaces that may form oxides in hidden cavities is not acceptable for sterilization in hydrazine-based fuels.

III. RECOMMENDATIONS

The following recommendations are made as a result of the work performed during this period:

1) Welding of steel or titanium parts that will see hydrazine fuels at sterilization temperatures should be done in an inert atmosphere, preferably in an inert gas purged glove box;

2) A welding development program should be implemented so that steel screens may be attached to other basic metals. A welded leak-tight system is preferred over the riveted joint chosen in this program;

3) An exhaustive test program should be initiated to determine the mechanics of fuel decomposition caused by metal oxides. The program should determine whether all metal oxides cause fuel decomposition or whether the process is caused by only a few of the metal oxides used in the material of construction.

IV. GENERAL REPORT

A. SYSTEM DESIGN AND ANALYSIS

The system schematic in its final form is presented in Fig. 1. No changes have been made since the final selection of components.

The system assembly and detailed fabrication drawings were completed during the report period and fabrication of the detailed parts was started. A complete drawing tree is presented in Fig. 2. At the completion of the report period all detail parts had been completed and preparations were being made to begin assembly of the LAB6002501 truss and the LAB6002519 nitrogen system assembly.

No significant problems occurred in the final stages of system design except for the fuel tank screen trap assemblies. During the previous report period an unsuccessful search had been made for titanium woven mesh screen. Titanium was the preferred material because the fuel tank was titanium and a joint between the tank and the screen assembly would be required. Different tank and screen materials would not allow the use of a fusion weld joint, which is the best type of joint to use from a leakage and compatibility standpoint. With titanium screen not available, stainless steel was selected as the best alternative material.

A program was set up to develop and acceptable joining technique for stainless steel to titanium. A general configuration for the screen trap assembly was established and is shown in Fig. 3.

Details B and C of Fig. 3 are the joint configurations initially attempted. Section IV.C of this report describes in detail the welding investigations that were made in an attempt to fabricate an acceptable joint. After it was concluded that welding could not be used, a program was set up to develop a riveted joint between the screen and the trap. The basic problem that could not be solved for the welded joints was oxide contamination caused by the welding, which resulted in fuel decomposition.

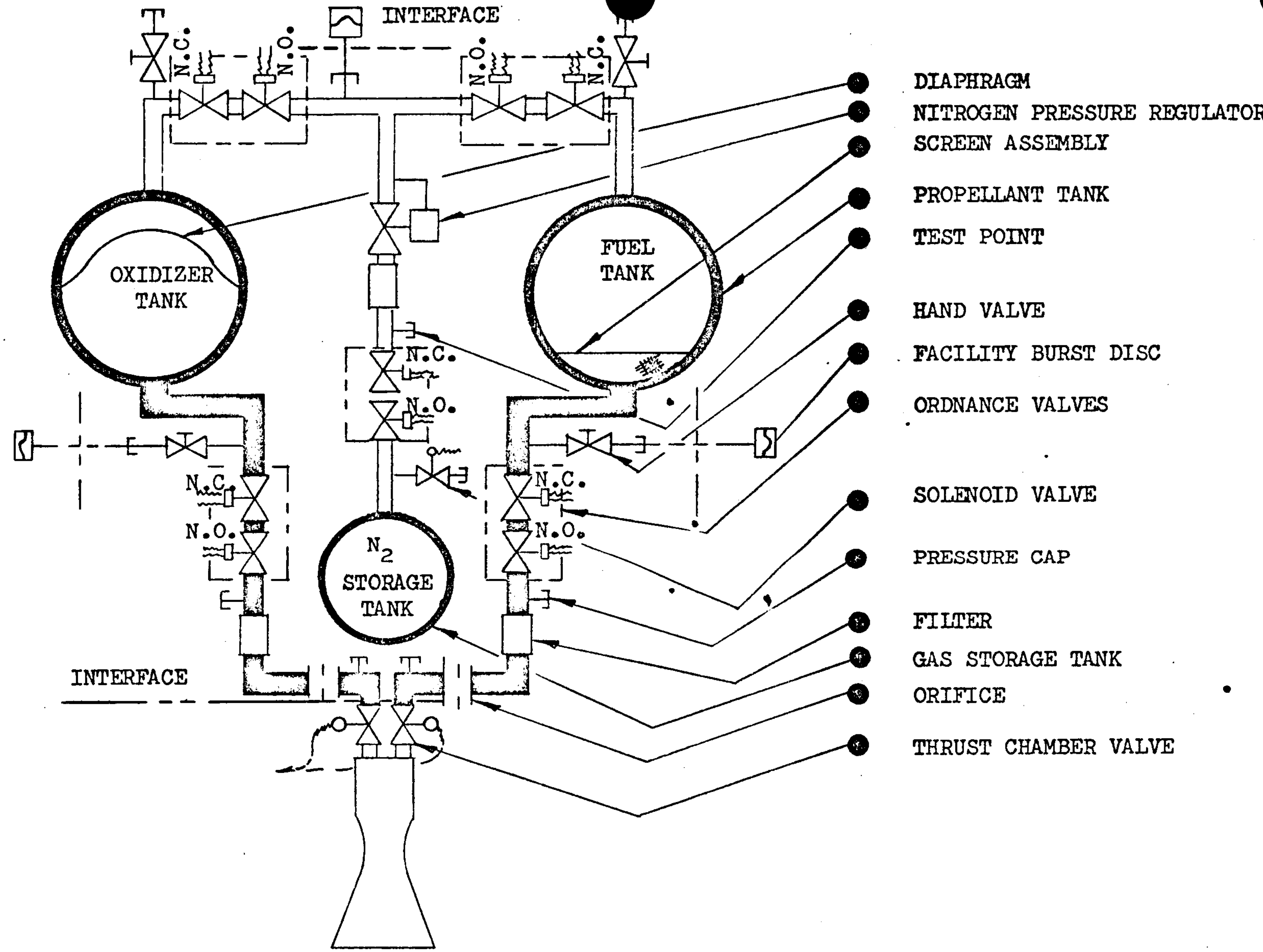


Fig. 1 Sterilizable Liquid Propulsion System

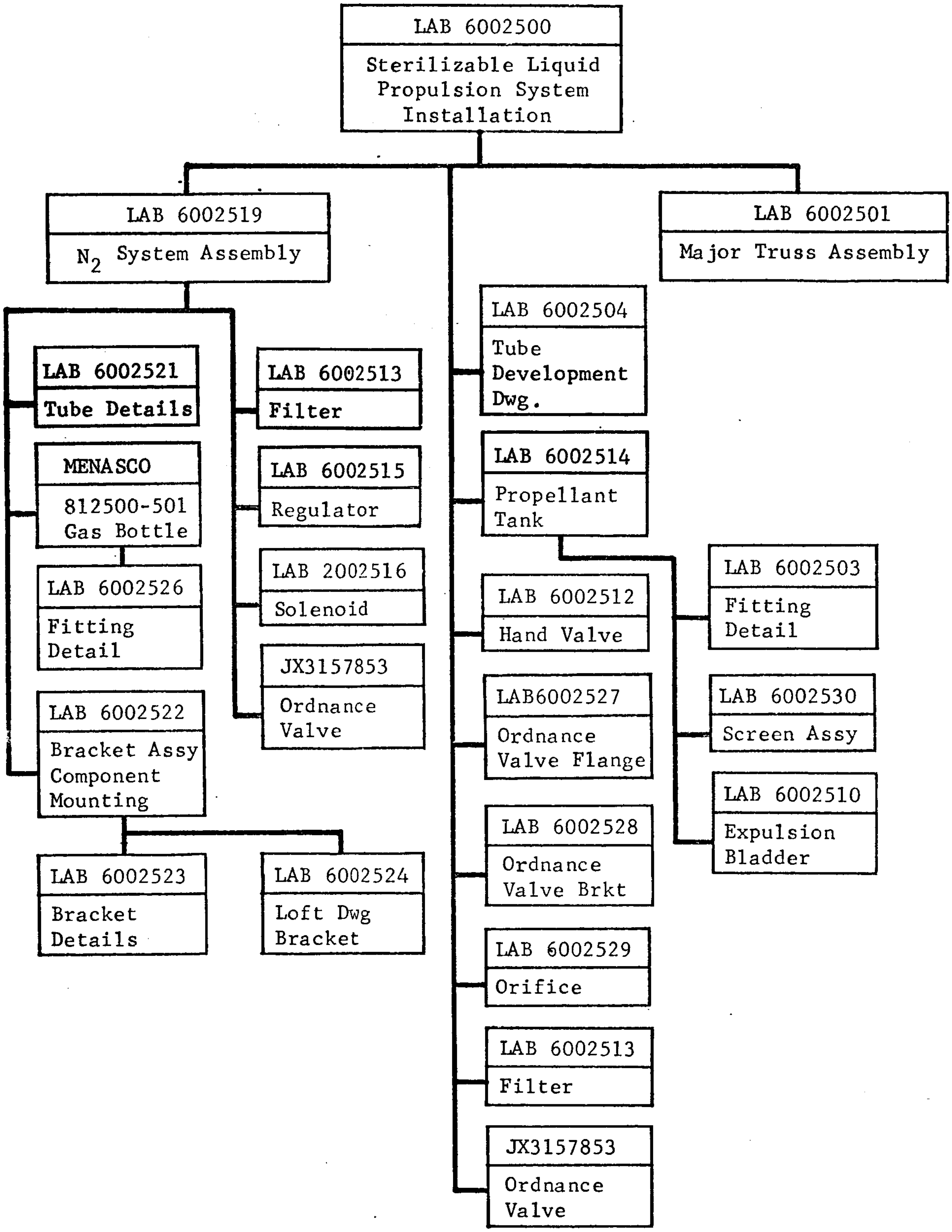


Fig. 2 Sterilizable Liquid Propulsion System Drawing Tree

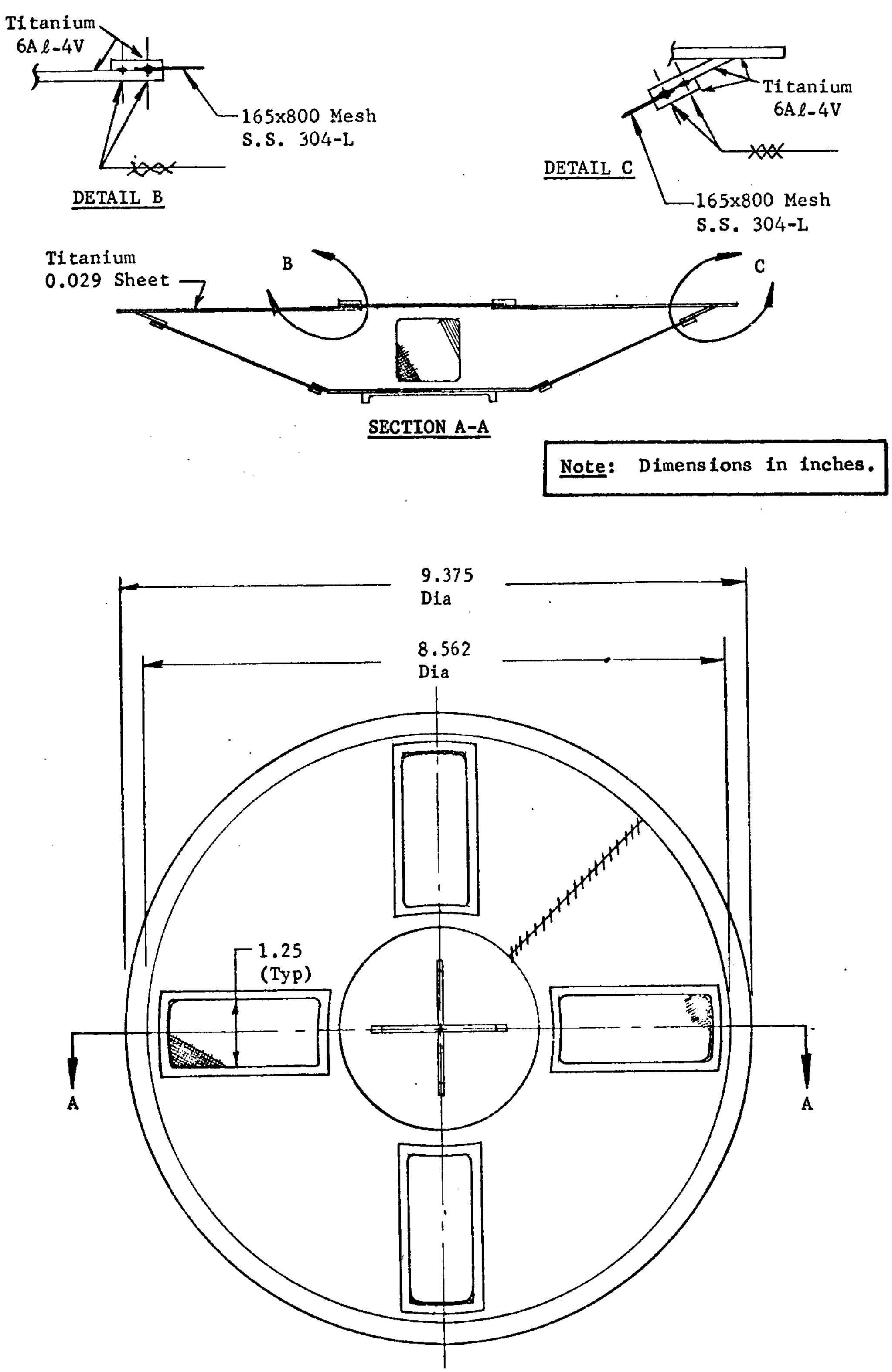


Fig. 3 Screen Trap Proposed Welded Configuration

The riveted joint would not be concerned with this problem since the precleaned parts would not be contaminated by riveting. However, a new problem could exist, joint leakage. With the weld joints leakage was not a problem. With a riveted joint leakage became a primary problem. Some preliminary leakage checks were made through a joint of stainless steel sheet riveted to stainless steel sheet. Both monel and aluminum rivets were used. The joints using the aluminum rivets were much tighter than the joints using monel rivets and were preferred from a fabrication standpoint. Another problem existed, however, with the use of aluminum in the trap assembly. This problem involved the passivation of the trap assembly using a mixture of water and MMH before installation in the fuel tank. A water/MMH mixture is used initially as a passivation fluid for safety reasons. If a decomposition reaction does occur the water diluent holds down the hazard of fire. After passivation with the mixture, a second passivation using pure MMH is normally done. While aluminum is completely compatible with pure MMH, it is not compatible with the water/MMH mixture. This makes it necessary to do the more hazardous passivation. Since the trap assembly is relatively large (9 in. diameter x 2 in. deep), a large vessel is required for passivation and a large quantity of MMH is needed. For these reasons every attempt was made to use monel rivets.

A second set of rivet joint samples were made. In this case, 1-in.-diameter windows of screen were assembled (Fig. 4) and checked for bubble point. Both monel and aluminum rivets were used to build assemblies. The assembly, using aluminum rivets, bubble point tested to 6 in. of water while the assembly using monel rivets was good for $3\frac{1}{2}$ in. of water. Since the trap assembly to be used in the fuel tank has a total depth of only 2 in., the monel rivet joint would be capable of meeting the required performance and was selected for trap fabrication.

The full-scale assembly of two traps was initiated and required approximately one month for completion. The screen window panels were bubble point tested twice in the assembly sequence. The first test was immediately after riveting. Special fixtures were used to check each window separately before major trap assembly. A second leak check was made of the completed trap assembly to obtain an overall bubble point. No further problems with bubble point of the screens occurred, with bubble points of 2.5 to 7 in. of water measured on individual windows, and 2 and 2.5 in. on the complete assemblies.

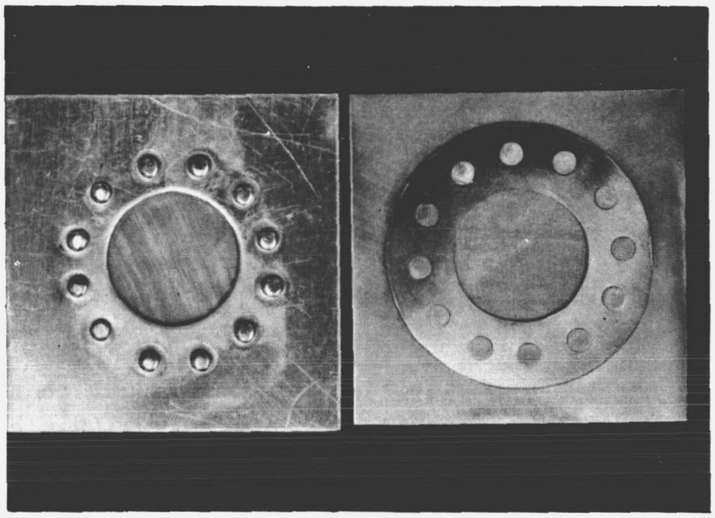


Fig. 4 Riveted Screen Samples

Welding of the cone section of the traps at the large diameter end to the flat sheet portion of the trap did cause a problem. Although an inert gas purge was used for the welds, a quantity of dark colored oxide was created in the acute angle. This area is not accessible for mechanical cleaning and a procedure for chemical cleaning had to be worked out. A mixture of nitric acid and HF was used, with great care taken that the solution did not contact the screen material. The reaction is a direct surface attack on the base metal allowing the oxide coating to lift off. Although this attack is not significant on sheet metal parts it is significant on the screen which has a large surface area to volume ratio.

Due to the weld oxide problem a 1-in.-diameter hole was cut in the cap, which was welded to the small diameter end of the cone. This allowed a final visual inspection of internal welding. The 1-in. hole was closed with a patch using blind rivets with one final leak check hole left in the center of the patch. After leak check this hole too was sealed with a blind rivet. The finished screen trap assembly is shown in Fig. 5.

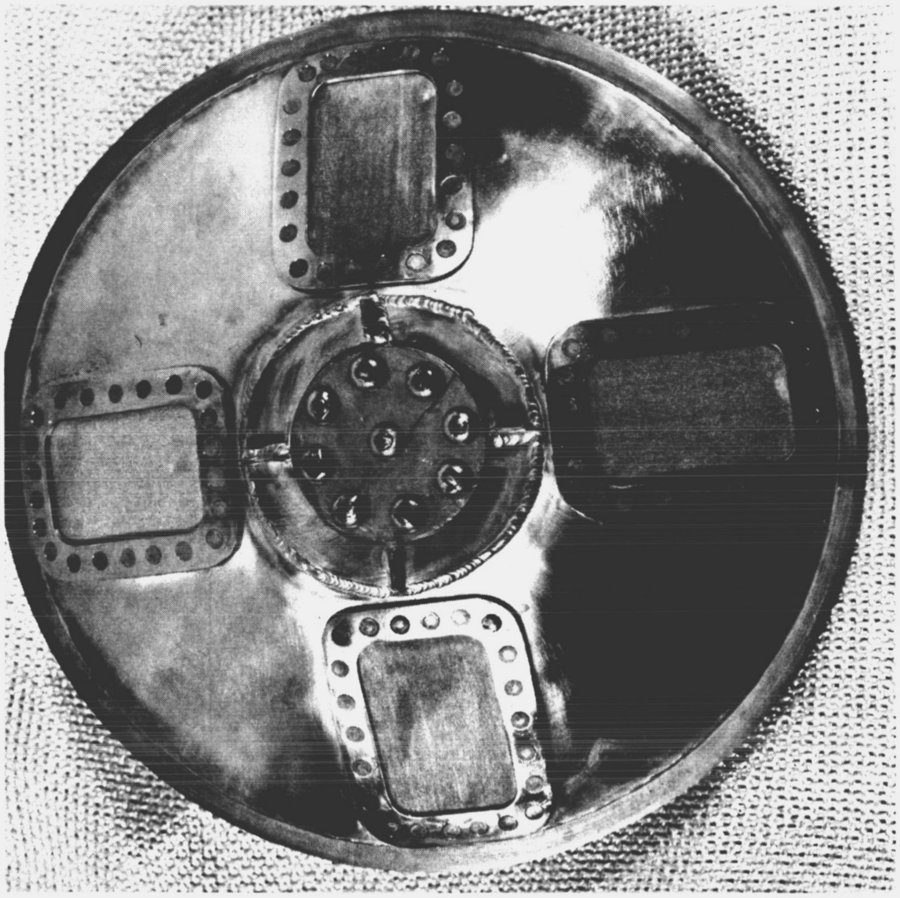


Fig. 5 Screen Trap Assembly

B. COMPONENT DESIGN AND DELIVERY

During this report period component deliveries were started and will continue through 14 July 1967, at which time all components necessary for the Phase II testing should be received. A summary of the status of components is listed in the following tabulation.

Component	Martin Marietta Part No.	Vendor and Part No.	Scheduled Delivery	Actual Delivery	Remarks
Pressurant Tank (1)	None	Menasco 812500-501	6/30/67	6/26/67	
Propellant Tanks (4)	LAB 6002514	Pressure Systems 80091-1 Ox 80092-2 Fuel	7/14/67 (2) 7/28/67 (2)		Date of 7/14/67 for two tanks has not slipped
Hand Valve (9)	LAB 6002512	Vacco NVB 32181	6/5/67	6/9/67 (1) 6/23/67 (8)	
Gas Regulator (2)	LAB 6002515	Sterer 35570	7/1/67		Delivery anticipated on 7/12/67
Solenoid Valve (2)	LAB 6002516	Sterer 35580	7/1/67	7/7/67	
Filter (4)	LAB 6002513	Western 20477-5	6/2/67	5/29/67	
Expulsion Bladder (3)	LAB 6002510	Dilectrix 1660-4	6/15/67	6/16/67 (1) 6/17/67 (2)	
Zero-G Screen (2)		Martin Marietta LAB 6002530	6/1/67	6/5/67	
Engine Control Valve (2)	None	Marquardt 228684 Ox 228683 Fuel	5/15/67	5/16/67	
Ordnance Valve (6)	None	GFE	7/14/67	11/28/66	
Engine (1)	None	Marquardt R4-D	9/1/67		No problem in delivery is expected
Throttling Valve (1)	None	GFE	7/14/67	7/7/67	

In each case a components engineer or a Martin Marietta area quality control man witnessed acceptance testing.

The only current problems concern the meeting of required delivery dates for the propellant tanks and the gas regulators. At the close of the reporting period the plan was to send a components engineer to the Los Angeles area to stay with both suppliers until the parts had been shipped. The tank assembly is the most complex and if slippage occurs it is expected to happen in this area. This item involves secondary suppliers in both the oxidizer and the fuel tank assemblies. At the close of the report period the expulsion diaphragms and the screen trap assemblies had been received by Pressure Systems and inspection of the parts was in progress. An extra diaphragm had been ordered to allow for at least one replacement during final tank assembly. In fact one diaphragm had been rejected at Pressure Systems because of a fold near the sealing ring and a small hole at a three-corner fold. Dimensional tolerances of the diaphragms in the seal area had not been within the drawing tolerance, however, the tank seal cavity will be tailored to fit the as-built diaphragm.

A problem occurred with the hand valves in that the valve bodies were initially rejected due to roughness and scratches in the valve seat area. After reworking the valves they were ready for acceptance and were shipped.

C. MATERIALS INVESTIGATION

The Material Engineering Section supported the program in several areas of test activity. During the report period a Freon and titanium compatibility test was conducted, the long-term exposure test of model propellant tanks was initiated, a program was conducted to clean and passivate the deliverable screen traps, and finally several small miscellaneous tests were conducted in support of the program.

1. Freon/Titanium Compatibility Test

Data developed by other investigators, namely NASA-MSC, Boeing, duPont, and Aerospace Corporation, have shown that titanium 6Aℓ-4V alloy is not compatible with Freon MF, but that it is compatible with Freon TF/Oxyfume 12 material. The decontamination agent in sterilization exposure contains Freon 12 which is equivalent to a DF or "difluoro" designation between MF-"monofluoro" and TF-"trifluoro" formulations. Therefore, it was decided to perform tests to ascertain the compatibility of the materials.

The problem involves the availability of chlorine in the Freon 12 and its effect on titanium. Specifically, it was desired to know if the decontamination atmosphere would initiate stress cracking or whether an existing structural flaw would propagate. Four specimens were tested. Each was a Langley sample stressed to 125,000 psi. Two specimens were notched in the area of maximum stress and two were not.

The test was run for 168 hr under the following conditions:

1) The decontamination mixture was 12% ethylene oxide and 88% Freon 12 at a concentration of 600 mg per liter of chamber volume;
2) Relative humidty was maintained at 45% ± 10%;
3) The temperature was 122 ± 1°F at all times. The decontamination gas was preheated to 122°F before introduction into the test chamber.

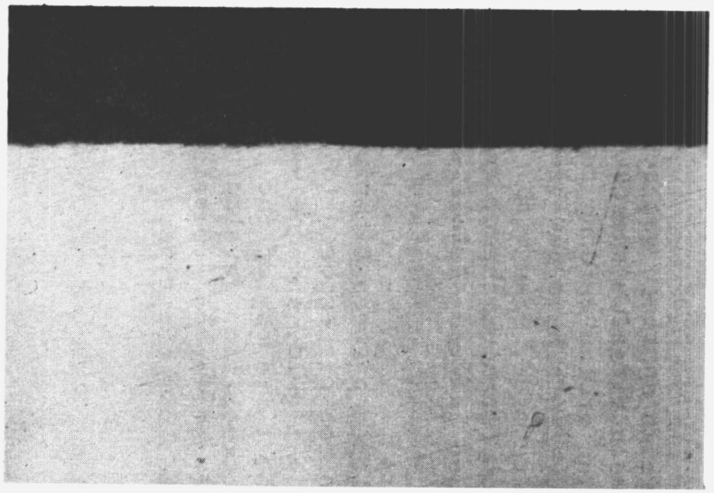
The photomonographs of the specimens shown in Fig. 6 show no detrimental effects resulting from the tests.

2. Long-Term Storage Test

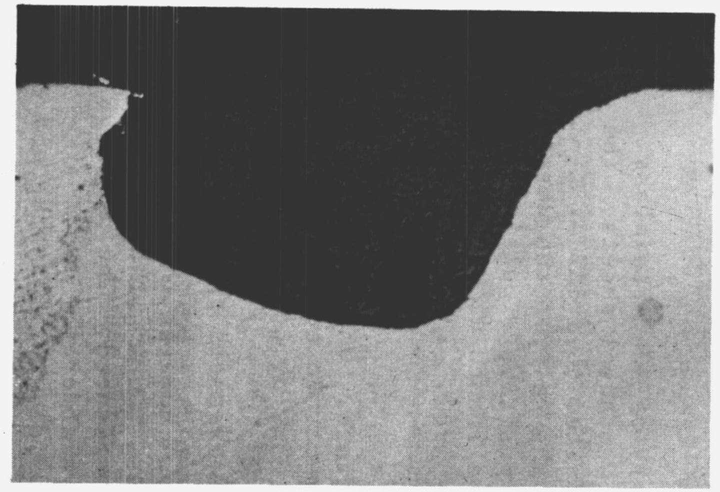
A long-term storage test has been initiated to determine whether materials that have been subjected to sterilization exposure in contact with propellants and then stored for one year at room temperature undergo any degradation of properties. The final combination of materials representing both the propellant tanks and the internal expulsion devices are being tested.

Eight small-scale tanks were fabricated, four representing fuel and four representing oxidizer tanks. Three of each have been exposed to the sterilization cycles and one each have been held as a control sample for later comparisons. Each tank was fabricated from titanium 6Aℓ-4V sheet stock using welded end closures. Figure 7 shows the test items. The fuel tanks have plumbing lines attached to allow for continuous monitoring of the vapor pressure because of the decomposition potential.

The oxidizer tanks contain a strip of TFE-FEP Teflon laminate and a NASA-Langley prestressed titanium specimen. The specimen is of 6Aℓ-4V titanium stressed to 125,000 psi having a weld in the area of maximum stress. The tank was loaded with N_2O_4 and exposed to sterilization temperatures for 600 hr. Exposure began on May 5 and ended on May 31.

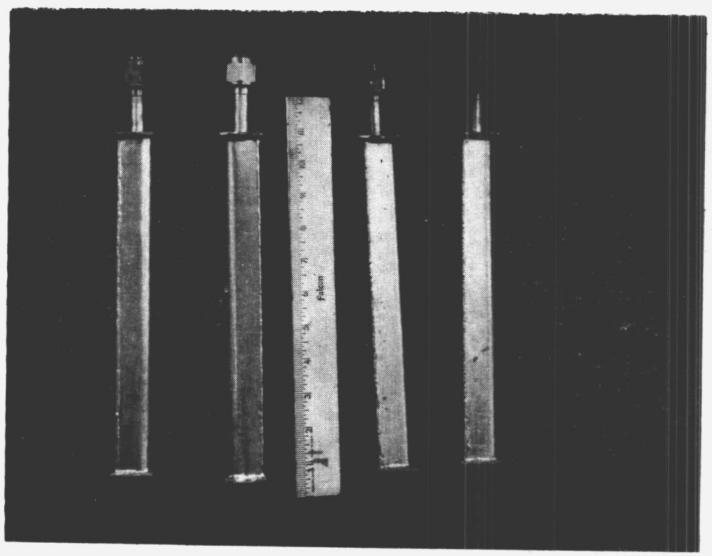


(a) Unnotched Specimen, Titanium 6Aℓ-4V (200X)



(b) Notched Specimen, Titanium 6Aℓ-4V (200X)

Fig. 6 Titanium 6Aℓ-4V Alloy Exposed to ETO/Freon 12



(a) Oxidizer

(b) Fuel

Fig. 7 Small-Scale Propellant Tanks for Long-Term Storage Tests

The fuel tanks contain a riveted assembly of 304L stainless steel screen sandwiched between 304L stainless steel sheets. The stainless steel sheets were subsequently riveted to a 6Aℓ-4V titanium sheet, which in turn were welded to the wall of the vessel. This represents the screen trap device for positive expulsion employed in the fuel tank. The vessels were loaded with MMH and exposed to sterilization temperature 12 May 1967. The 600-hr exposure concluded on 6 June 1967.

The vessels are now held in ambient storage. One each will be opened and examined in four-month increments to establish a year-long storage history.

During the temperature exposure the N_2O_4 vessels exhibited normal vapor pressure-temperature histories. However the fuel vessels exhibited erratic pressure histories. During the exposure pressures from 60 psig to 143 psig were experienced. The higher pressure was a peak value experienced 7 days after the start of the test. The pressure level gradually subsided until at the end of the test pressure levels of 75 psig were present. The pressure transient suggests contamination of oxides during fabrication. This effect is discussed in the next section.

3. Screen Welding

Design - Late in March a screen trap design approach was selected using steel screens seam welded between titanium sheets as shown in Fig. 3, pending verification testing of the welding technique. Subsequent welding and compatibility tests have now been completed. Two series of test specimens were made: one with stainless steel screening sandwiched between titanium sheet, and one with stainless steel screening sandwiched between stainless steel sheets.

The test coupons of steel screen sandwiched between titanium sheet were exposed to MMH at 275°F. One coupon was exposed to vapors only, one was completely submerged in liquid, and one was exposed to a vapor-liquid interface. On the third day of the specimen submerged in liquid MMH caused decomposition developing pressures in the test vessel up to a relief setting of 200 psig. Further testing was discontinued. Figure 8 shows the type of weld obtained by the seam welding technique.

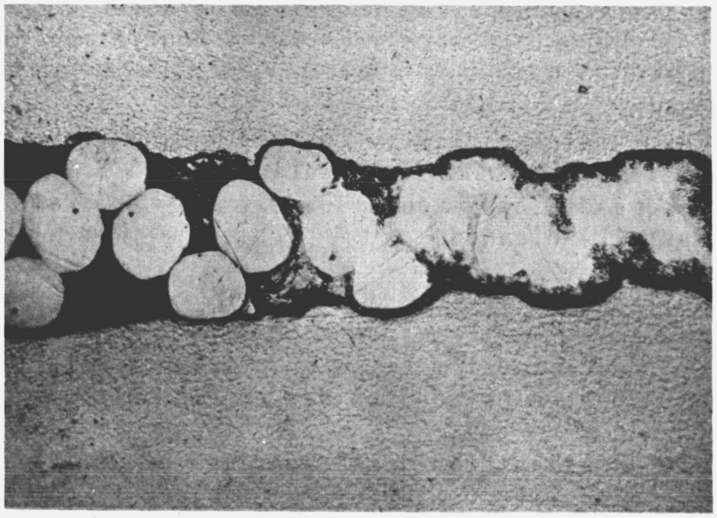


Fig. 8 Micrograph of Stainless Steel 304L Screen Seam Welded between Sheets of 6Aℓ-4V Titanium (200X)

From the results of the above testing, coupons of steel screen sandwiched between stainless stell were fabricated. Examination indicated the quality of weld was not improved over that shown in Fig. 8. Various machine settings of the seam welder always resulted in the formation of heavy oxides. Attempts to provide an inert atmosphere at the welding heads were unsuccessful. These results dictated that the welding of screens be abandoned because the combination of heat, water, oxidizing atmosphere, and small cavities could not be eliminated. A riveted screen sandwich design was adopted to eliminate welding of dissimilar metals.

Fabrication - Despite precautionary measures to make the cone welds in an inert atmosphere some oxides were formed on both the inside and outside of the trap. Our background in contamination of parts designed for fuel service indicated the quantities of oxides formed was unacceptable. The oxides formed externally were easily removed by buffing with abrasive cloth. The oxides formed internally had to be removed chemically since the seam was inaccessible.

The oxides were successfully removed by very carefully applying hydrochloric acid followed by a solution of nitric acid fortified with 17% hydrofluoric acid. Extreme care was taken not to expose the screen material.

By repeatedly applying the cleaning solution and inspecting the parts, the oxides were removed without damaging the screen material.

Cleaning was verified by installing the traps in a bomb device containing 100% MMH and heating to 275°F for 76 hr. The bomb pressure did not exceed 90 psig and the traps were accepted as successfully cleaned.

4. Miscellaneous Testing

Several additional materials were exposed to propellants for 600 hr at 275°F. The results are as follows:

1) A transition joint specimen of 304L stainless steel and titanium alloy was subject to MMH exposure. No attack was noted on the specimen and no fuel decomposition occurred;

2) A welded 6Aℓ-4V titanium bellows section was exposed to N_2O_4. No attack was noted;

3) Ardeform 301 stainless steel was exposed to N_2O_4. The degree of attack was substantially less than that of any other 300 series steel alloy. Although the amount of the viscous adduct was substantially less, the material is not considered suitable for propulsion system construction when sterilization is a requirement;

4) Fluorosint was exposed to N_2O_4. No significant change in weight or dimensions was noted.

A review of our records indicates that a transition joint of titanium-aluminum has not been exposed to N_2O_4 as planned. This test will be performed during the next report period.

D. COMPONENT TESTING AND FACILITIES

1. Test Procedures

Preparation of procedures for Task II testing was completed and submitted to JPL in early June. Preparation of Task IV procedures was in progress at the end of this reporting period. Work on these procedures, which include those for installing the module in the decontamination/sterilization chamber and for conducting the firing test, will be in progress throughout the coming month.

2. Component Test Progress

At the end of the reporting period, initial functional tests had been completed on the ordnance valve and the two thrust chamber valves. Testing of the filter was in progress at the end of the period, and the hand shutoff valve test item was being prepared for test immediately following the filter.

Results of the functional tests of the ordnance valve and the thrust chamber valves are shown on the data sheets in Fig. 9 and 10. Performance of the test items was acceptable in all respects. The rest of the test items, namely, the hand shutoff valve, regulator, solenoid valve, and propellant tanks will be functionally tested in the next reporting period.

H40107

Sterilizable Liquid Propulsion System

TASK II

SUMMARY DATA SHEET

COMPONENT: Name: Ordnance Valve
Part No.: J315-7853
Serial No.: 015

	Pre-sterilization	Mid-sterilization	Post-sterilization
A. Leakage Rate, Helium (scc/sec)			
Internal:	zero		
External:	zero		
B. Response $\left(dP_o/dt\right)$(psi/sec)	N/A	N/A	
C. Pressure Drop, Design Flow (psi)	N/A	N/A	

Fig. 9 Performance Data, Ordnance Valve

H40107

Sterilizable Liquid Propulsion System

TASK II

SUMMARY DATA SHEET

COMPONENT: Thrust Chamber Valves

		Pre-sterlization	Mid-sterilization	Post-sterlization
A. Oxidizer Valve, S/N 575				
1. Pull-in Voltage (VDC)	Max:	14.0		
	Min:	14.0		
2. Opening Response (sec)	Max:	0.0120		
	Min:	0.0120		
3. Closing Response, (sec)	Max:	0.0084		
	Min:	0.0064		
4. Pressure Drop, Design Flow (psi)		27.5		
5. Insulation Resistance (megohms)		500 +		
B. Fuel Valve, S/N 576				
1. Pull-in Voltage (VDC)	Max:	11.5		
	Min:	11.5		
2. Opening Response (sec)	Max:	0.0084		
	Min:	0.0081		
3. Closing Response (sec)	Max:	0.0088		
	Min:	0.0083		
4. Pressure Drop, Design Flow (psi)		13.8		
5. Insulation Resistance (megohms)		500 +		

Fig. 10 Performance Data, Thrust Chamber Valves

Photos of the test fixtures for the thrust chamber valves and the filter are shown in Fig. 11 and 12.

3. Test Facilities

Component Funtional Test Fixtures - Assembly of all test fixtures for the component functional tests has been completed with the exception of the fuel tank loading fixture, which is in the process of being cleaned and passivated for MMH service. The test fixtures for the thrust chamber valves and the ordnance valves have been used in test.

Design drawings of the component holding fixtures for use in the sterilization chamber have been completed and were being checked for release at the end of this reporting period. Fabrication of the component holding fixtures is scheduled for completion next month, consistent with the anticipated delivery dates for the last of the test components.

Sterilization Chamber - Assembly of the decontamination/sterilization chamber was completed, and checkout tests were conducted that culminated in qualification tests of the chamber in both the sterilization and decontamination configurations. Figure 13 shows the chamber control console and data recording system. Figure 14 shows the open chamber with the shroud removed. The electrical heaters (heat source for sterilization tests) are located on the lower flange of the shroud. Figure 15 is a view into the chamber showing the blower assembly and the hot water heat exchanger. The hot water heat exchanger is the heat source for ETO decontamination tests.

Check runs were completed on the chamber and its control systems, culminating in qualification testing of the chamber in both the sterilization test configuration and the decontamination test configuration.

The results of the sterilization chamber qualification (temperature distribution) test are shown in Tables 1 and 2. Note that the reference temperature history during the automatically controlled temperature ascent phase deviated a maximum of 12°F from the desired program; however, this deviation will be substantially reduced by reshaping the temperature controller cam.

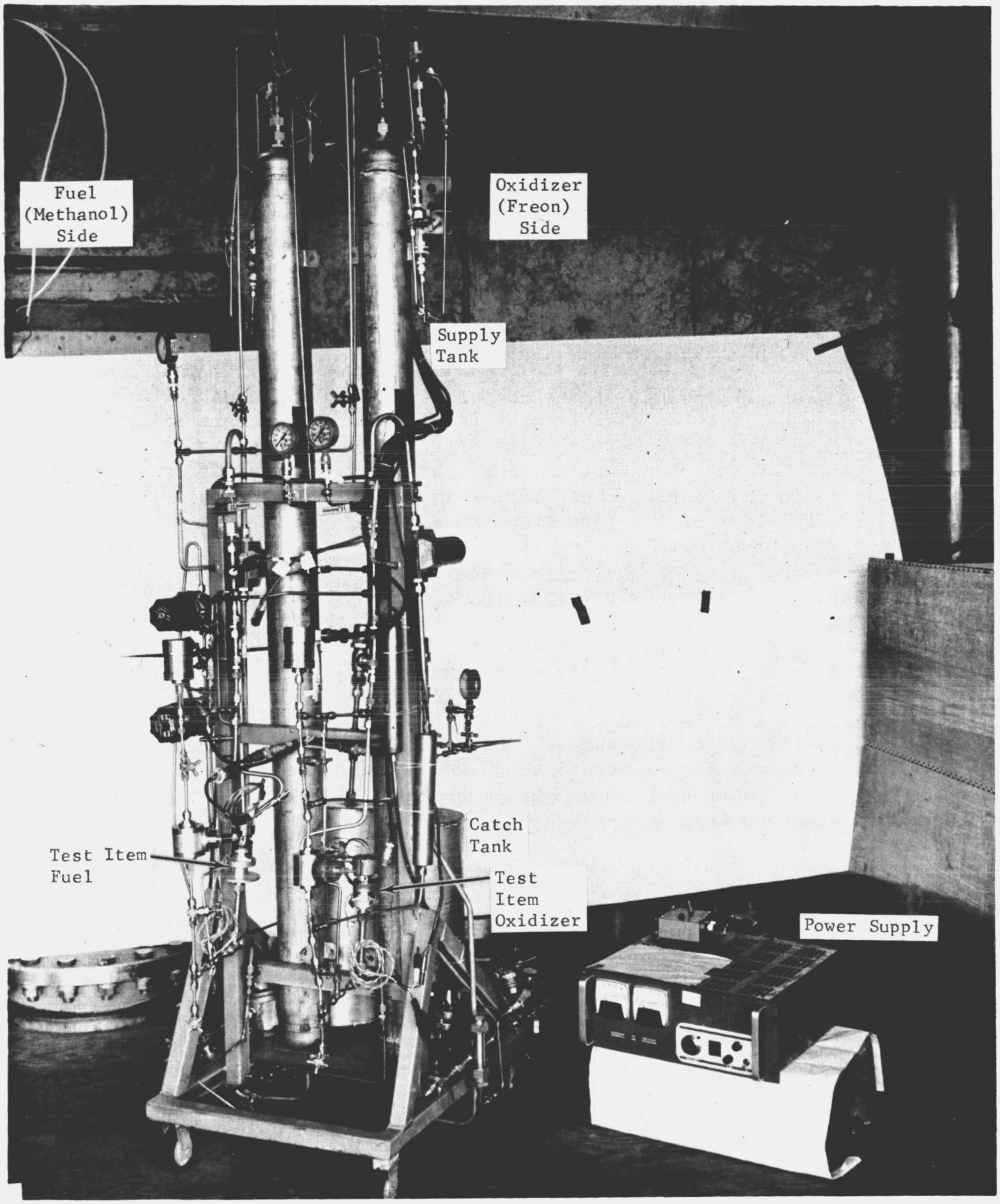


Fig. 11 Test Fixture, Thrust Chamber Valves

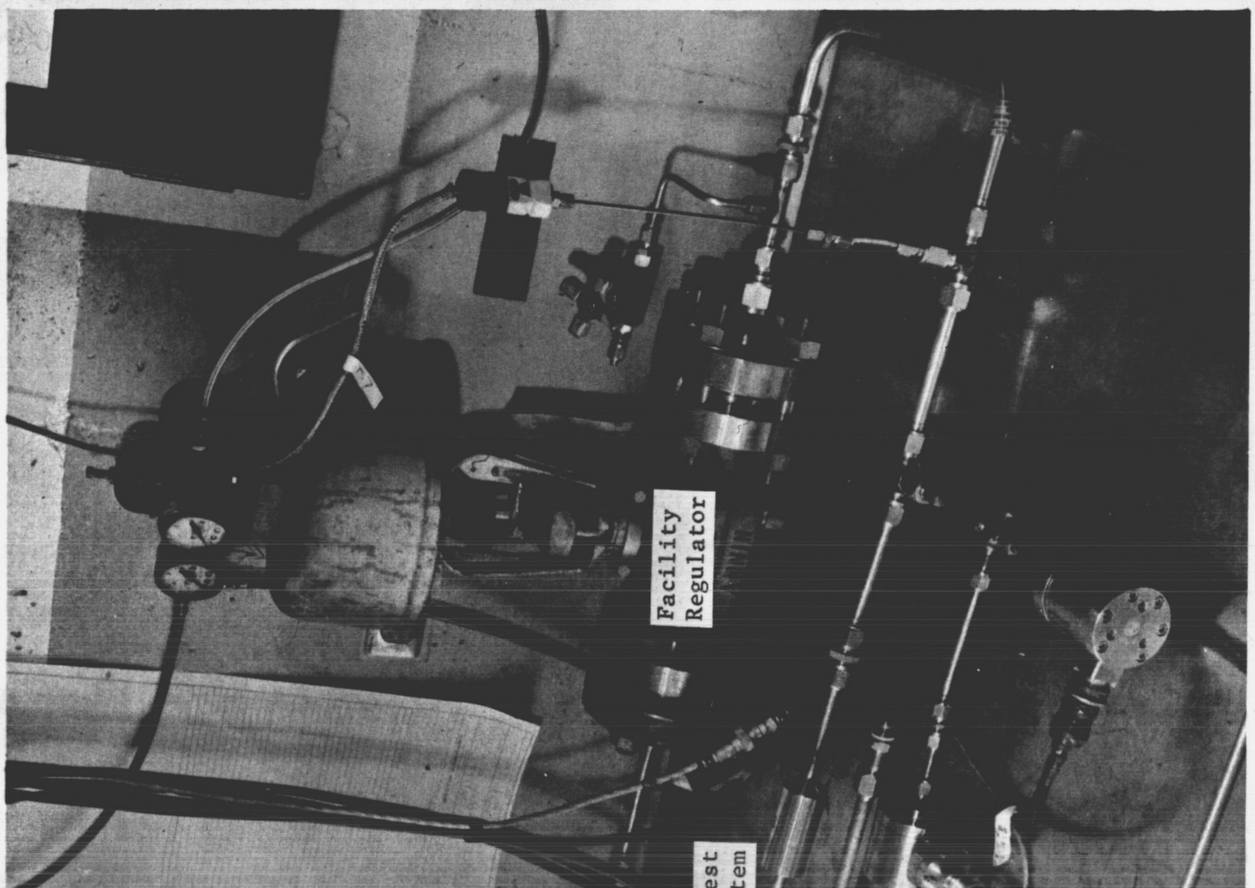


Fig. 12 Test Fixture, Filter

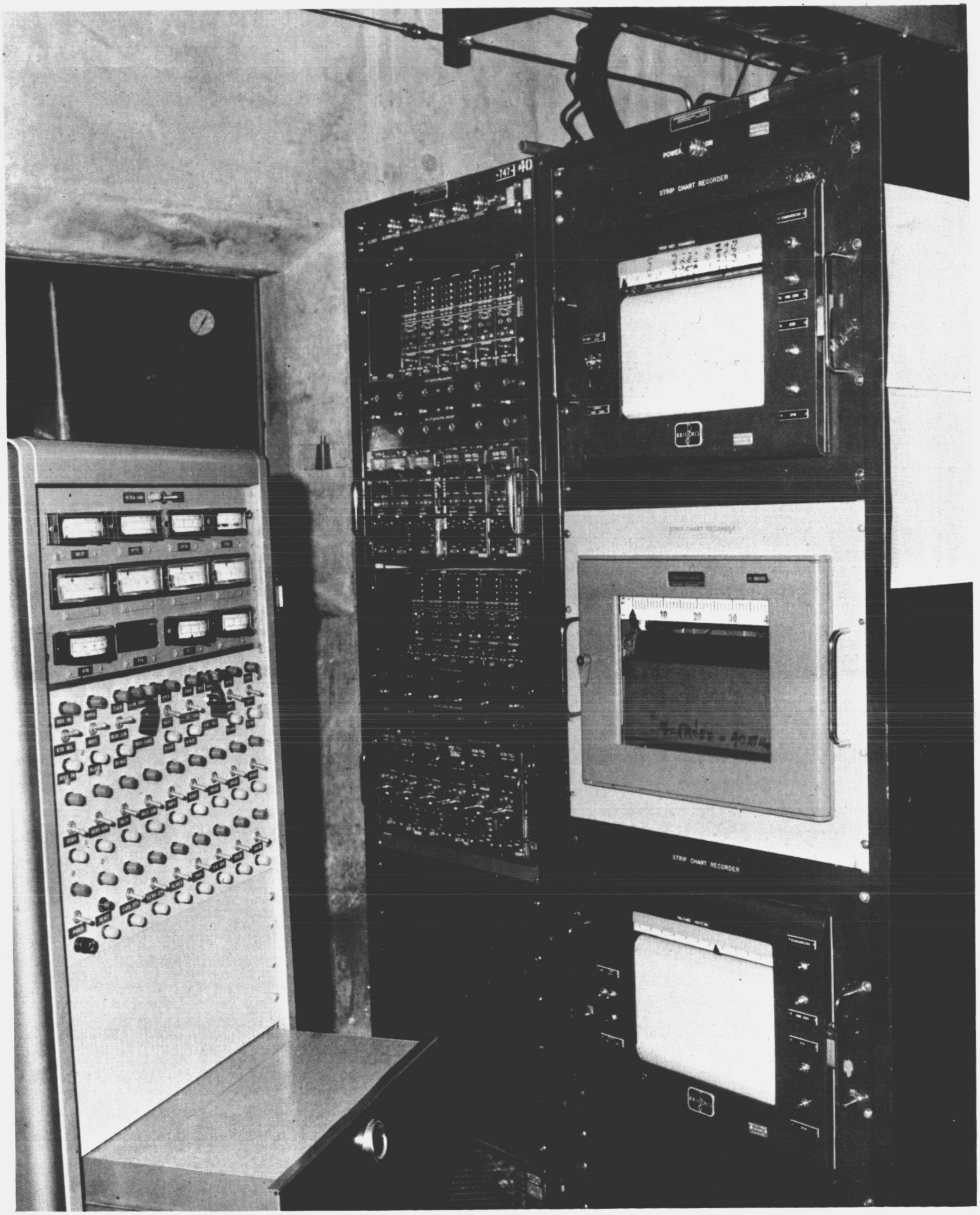


Fig. 13 Sterilization Chamber Control Console and Data Recording System

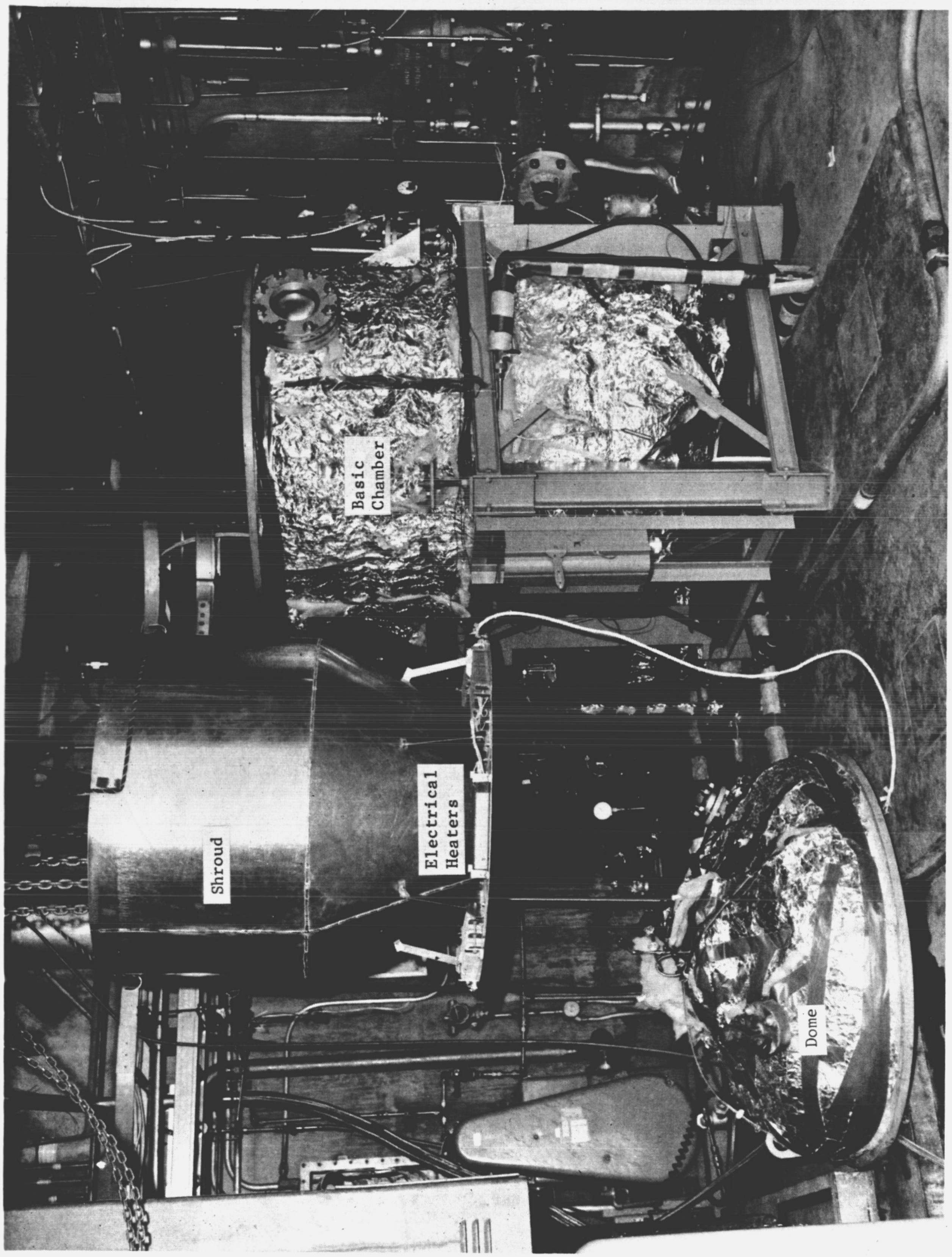


Fig. 14 Sterilization Chamber, Shroud and Dome Removed

Fig. 15 Sterilization Chamber, Internal View

TABLE 1

STERILIZATION CHAMBER QUALIFICATION

TEMPERATURE ASCENT AND CONSTANT TEMPERATURE PHASES

TEST DATA

ELAPSED TIME HR:MIN	T_{ref}-°F DES.	T_{ref}-°F ACT.	DISTRIBUTION TEMPERATURES - DEVIATION FROM ACT. T_{ref}-°F T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
			Temperature Ascent Phase									
0:00	72	74	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0:10	78	79	0	-1	0	0	0	0	0	0	0	0
0:20	83	83	0	-1	0	0	0	0	0	0	0	0
1:00	106	105	-2	-2	-1	-1	-2	-1	-1	-1	-1	0
1:10	112	113	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2
1:20	117	120	-1	-1	0	0	0	0	-1	-1	-1	-1
2:00	140	145	-2	-2	-1	-1	0	0	0	+1	0	+2
2:10	146	151	-2	-2	-1	-1	-1	-1	-1	-1	-1	+1
2:20	151	158	-2	-2	-2	-2	-2	-1	-2	-1	-1	0
3:00	174	186	-3	-3	-2	-2	+1	0	0	+1	0	+1
3:10	180	190	-3	-3	-2	-2	0	-1	0	0	0	+1
3:20	185	194	-2	-3	-2	-2	0	0	0	0	0	+2
4:00	207	214	0	-1	+1	0	+2	+1	+1	+1	+1	+1
4:10	213	219	-2	-3	-1	-1	-1	-1	0	0	-1	0
4:20	218	223	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
5:00	241	247	-1	-2	0	0	+2	+1	+1	+1	+1	+3
5:10	247	252	-3	-4	-3	-2	-2	-2	-2	-2	-2	-1
5:20	252	257	-2	-3	-1	-1	0	-1	-1	-1	-1	-1
5:50	269	272	-1	-2	-1	-1	-1	-1	-1	-1	-1	-1
			Constant Temperature Phase									
0:10	275	273	0	0	+2	+1	+4	+3	+3	+4	+3	+4
0:14	275	272	-3	-3	-3	-3	-5	-3	-4	-5	-3	-3
0:17	275	273	0	-1	+1	+1	+3	+2	+2	+3	+2	+4
0:21	275	272	-4	-5	-4	-4	-5	-3	-4	-4	-4	-3
0:24	275	273	0	-1	+1	0	+4	+2	+2	+3	+2	+4
0:27	275	272	-3	-3	-3	-3	-3	-2	-3	-4	-3	-4
0:32	275	273	+1	0	+1	+1	+2	+2	0	0	0	0

TABLE 2

STERILIZATION CHAMBER QUALIFICATION

TEMPERATURE DESCENT PHASE

TEST DATA

ELAPSED TIME HR:MIN	DES.	ACT.	DISTRIBUTION TEMPERATURES - DEVIATION FROM ACT. T_{ref} - °F T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
			Temperature Descent Phase									
0:00	275	273	+1	0	+1	+1	+2	+2	0	0	0	0
0:10	269	260	-8	-8	-8	-7	-8	-8	-8	-8	-8	-8
0:20	264	252	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
1:00	241	231	-5	-5	-5	-4	-5	-5	-5	-5	-5	-5
1:10	235	227	-5	-5	-6	-5	-6	-6	-6	-6	-6	-6
1:20	230	222	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
2:00	207	206	-3	-3	-3	-3	-4	-3	-4	-4	-4	-4
2:10	201	203	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4
2:20	196	199	-4	-4	-4	-3	-4	-4	-4	-4	-4	-4
3:00	174	182	-5	-5	-5	-4	-4	-4	-4	-4	-5	-5
3:10	168	178	-5	-5	-5	-4	-5	-5	-5	-4	-5	-5
3:20	163	172	-5	-5	-6	-5	-5	-4	-4	-5	-5	-4
4:00	140	149	-4	-4	-4	-4	-2	-4	-4	-3	-3	-4
4:10	134	143	-4	-3	-2	-2	-4	-3	-2	-2	-4	-2
4:20	129	138	-3	-3	-2	-3	-2	-1	-2	-4	-3	-1
5:40	83	89	+1	+1	+1	+1	+1	+1	+1	+1	+1	+2
5:50	78	82	+1	+1	+1	+1	+1	+1	0	0	0	0
6:00	72	76	+2	+2	+2	+2	+1	+1	+1	+1	+1	+2

The significant results indicated by the distribution temperature data are shown by the maximum temperature spreads summarized in the following tabulation.

Phase	Maximum Temp Spread (°F)	Allowable Spread (°F)
Temperature Ascent	5	±7.2
Constant Temperature (275°F)	5*	±3.6
Temperature Descent	3	±7.2
*Within allowable spread.		

The locations of the distribution temperature thermocouples are shown in Figure 16.

As a result of the above qualification testing, it has been concluded that the existing sterilization chamber configuration is satisfactory for use in the program. The programed controller cam contour will be modified to provide temperature ascent and descent rates which more closely adhere to the desired program.

The results of the ETO decontamination chamber qualification test are shown in Fig. 17 (temperature ascent and descent histories), and in Table 3 (temperature distribution data). The general results of the qualification test were as follows:

1) The chamber programed heating and cooling system performed satisfactorily, in that the temperature ascent history adhered to the desired program within 3°F at all times, and the temperature descent history adhered to the desired program within 2°F at all times. In addition, the control system demonstrated the capability of maintaining chamber temperature at a constant value with a variation of not more than ±1.5°F;

2) Temperature gradients in the chamber were acceptable, as evidenced by the following maximum spreads in distribution temperatures.

Phase	Maximum Temp Spread (°F)	Allowable Spread (°F)
Temperature Ascent	5	±7.2
Constant Temperature	1	±3.6
Temperature Descent	1	±7.2

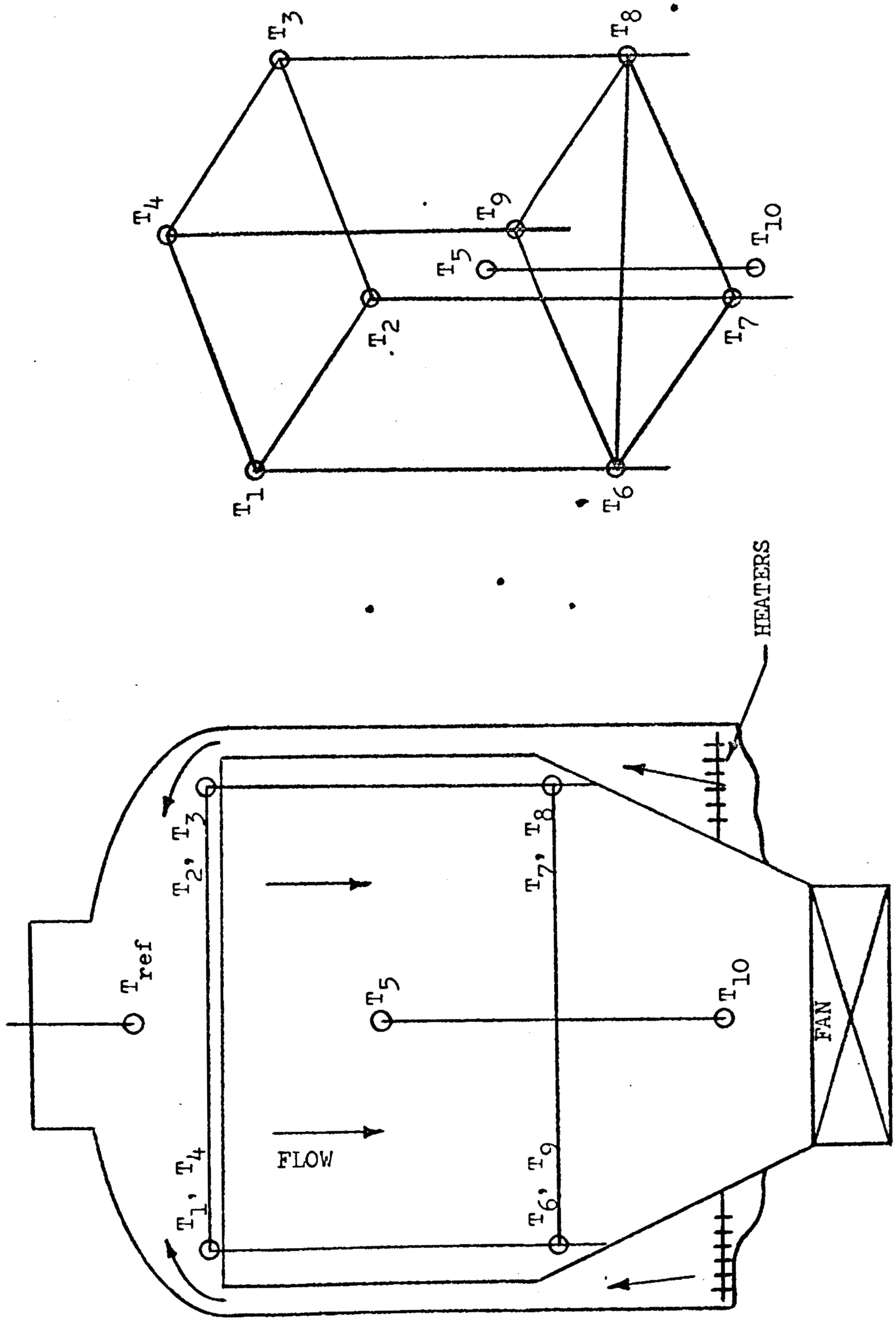


Fig. 16 Sterilization Chamber Qualification Distribution Thermocouple Array

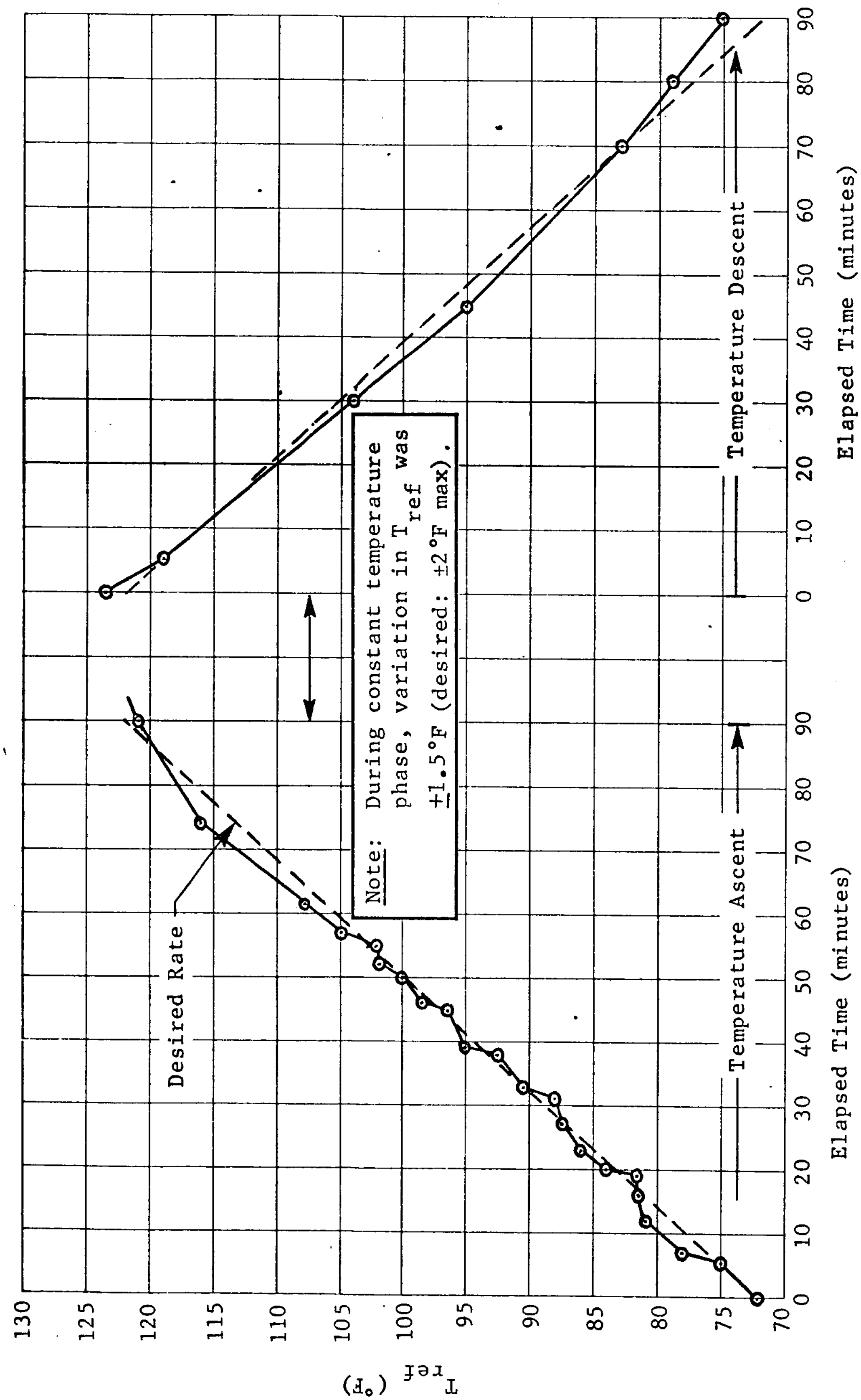


Fig. 17 Decontamination Chamber Qualification Reference Temperature History

TABLE 3

ETD Decontamination Chamber Qualification Test

DATA SHEET

Time - mins.	$T_{ref.}$ °F	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
		Distribution Temperatures- Deviation from $T_{ref.}$ - °F									
	-- Temperature Ascent Phase --										
0	72	-1	-1	-1	-1	0	0	0	-1	-1	-1
7	78	+1	+2	+3	+3	+4	+4	+3	+2	+2	+4
20	84	+1	+3	-2	-2	-1	-1	-1	+1	+1	+2
32	88	0	0	0	0	0	0	0	0	0	0
40	95	+1	+2	+2	+2	+3	+3	-1	-1	-1	0
50	100	-1	-1	-1	-1	-1	-1	-1	0	-1	0
62	108	+2	+2	+3	+3	+3	+2	+2	+2	+2	+3
74	116	0	+1	0	0	+1	+1	+1	+1	+1	+2
90	121	-1	0	0	0	0	0	0	0	0	+1
	-- Constant Temperature Phase --										
0	121	-1	0	0	0	0	0	0	0	0	+1
10	123	-1	0	-1	-1	0	0	0	0	-1	0
20	126	-3	-2	-2	-2	-2	-2	-2	-2	-2	-2
26	126	-2	-2	-1	-1	-1	-1	-1	-1	-1	-1
32	124	-2	-2	-1	-1	-2	-1	-1	-1	-2	-1
35	126	-2	-2	-2	-2	-2	-1	-2	-2	-2	-1
47	123	-2	-2	-2	-1	-1	-1	-1	-1	-1	-1
65	124	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
	-- Temperature Descent Phase --										
5	119	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
30	104	-2	-3	-3	-3	-3	-3	-3	-3	-3	-3
45	95	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
70	83	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
80	79	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
90	75	-1	-1	-2	-1	-1	-1	-1	-1	-1	-1

The design drawings for installation of the propellant vapor detectors at the sterilization chamber have been released, and fabrication will progress to completion in the next reporting period. The oxidizer vapor detector will be encapsulated within a pressure chamber to permit operation at the 22-psia chamber pressure used during ETO decontamination (Task IV). The fuel vapor detector will not be enclosed, since the detector will only be used during the ambient-pressure dry heat sterilization tests.

A check run has been completed on the ETO decontamination chamber humidifier system, with successful results. The check run demonstrated that relative humidity could be maintained between 45% and 55% during the most difficult part of the test, i.e., the temperature ascent phase, using manual control of the steam injection valve and monitoring the electric hygrometer signal.

The above-described humidity system checkout was made without ETO, since the electrohygrometer compatibility testing has not been concluded. Planned testing of the electrohygrometer was delayed because the broad band sensor was not available; however, the equipment is now available and the testing will be resumed.

Laminar Flow Bench - The Class 100 laminar flow bench installation is progressing on schedule. Remodeling of the clean room has been completed and flow bench is to be installed early in the next report period. A completion date of 14 July 1967 is expected.

Instrumentation Accuracy - A test program to verify the instrumentation accuracy of the Cold Flow Laboratory was completed. A detailed report was issued to the contract technical monitor on 9 June.

Typical empirical 2σ accuracies for pressure measurements using the nominal 2% full-scale system accuracy technique were better than 1%. An in-system stimulus calibration was performed on the same transducers to demonstrate the nominal 1% full-scale accuracy capability and the typical 2σ accuracies were better than 0.32% full-scale on all recorders. A 4-hr drift evaluation of the same parameters indicated a slight degrading effect of system accuracies. Accuracy varied with the type of recorder used. Typical end-to-end system accuracies over a 4-hr period were better than 0.26% full scale using the CEC recorder, 0.32% full scale using Bristol recorder, and 0.68% full scale using a Sanborn recorder.

A simulated dynamic stimulus was used to demonstrate the merit of electronically filtering dynamic signals that have frequency components beyond the recorder response. This filtering was performed at the data amplifier. Typical data showed no significant change in the accuracy of the CEC and Bristol recording. A 250 Hz input to the Sanborn recorder produced an error of 9.58% full scale. Electronic filtering to 10 Hz reduced this error to 0.57% full scale.

Typical 2σ accuracies for thrust measurements were better than 0.37% full scale over a 4-hr period.

Temperature data acquisition and recording indicated a better than 0.80% full-scale accuracy over a 4-hr period for thermocouples subjected to a temperature range of -100°F to +250°F. The platinum temperature probe demonstrated a 0.12% accuracy over the same period.